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NATIONAL WATER QUALITY MONITORING COUNCIL

Working Together for Clean Water

Sensor Signal Integrity and Data Quality Management: Who is Doing What?

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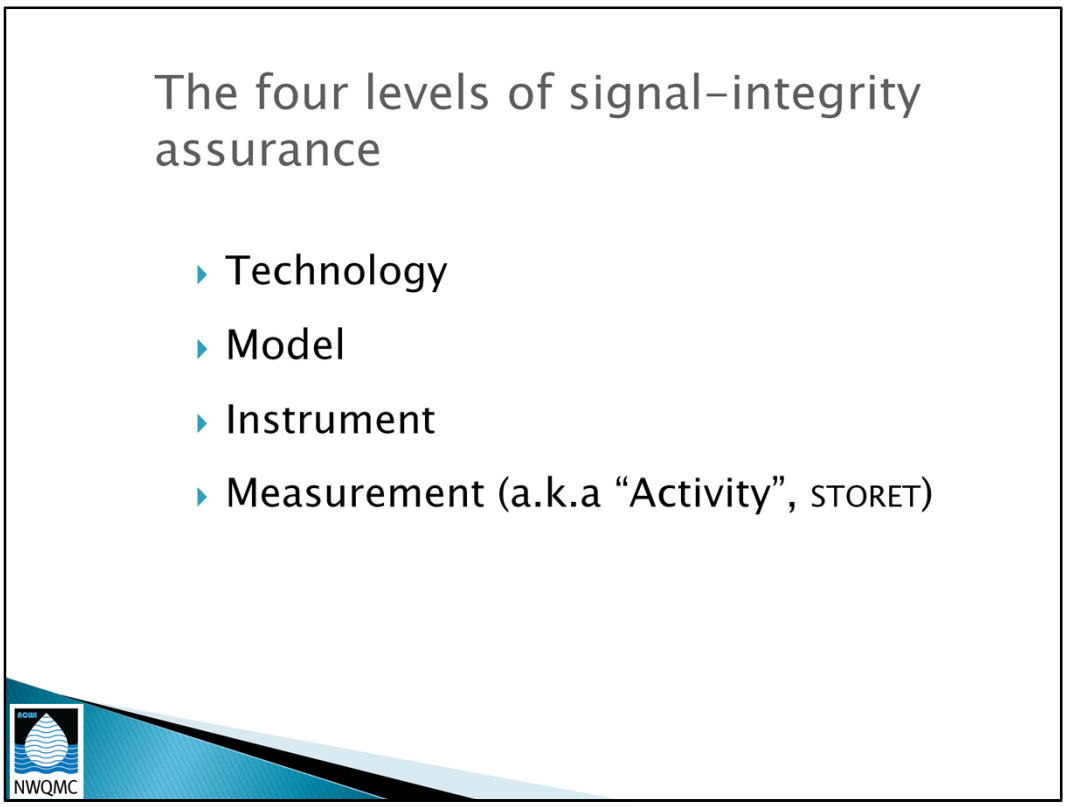
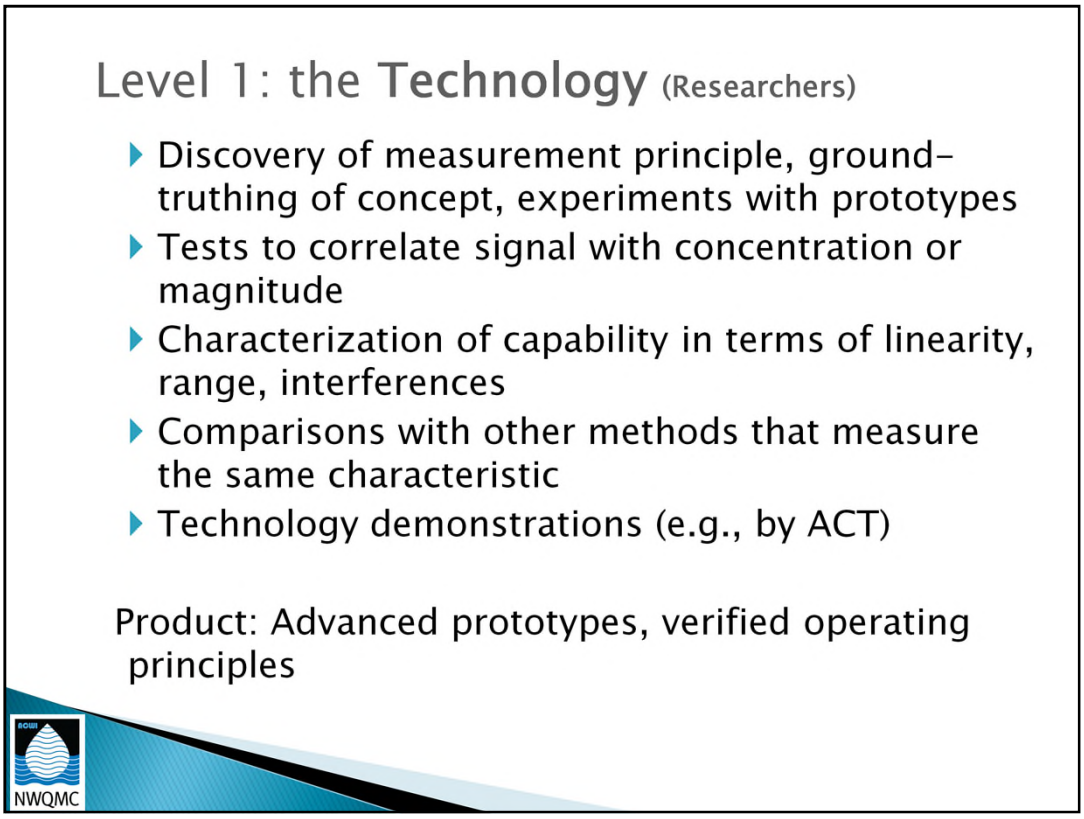
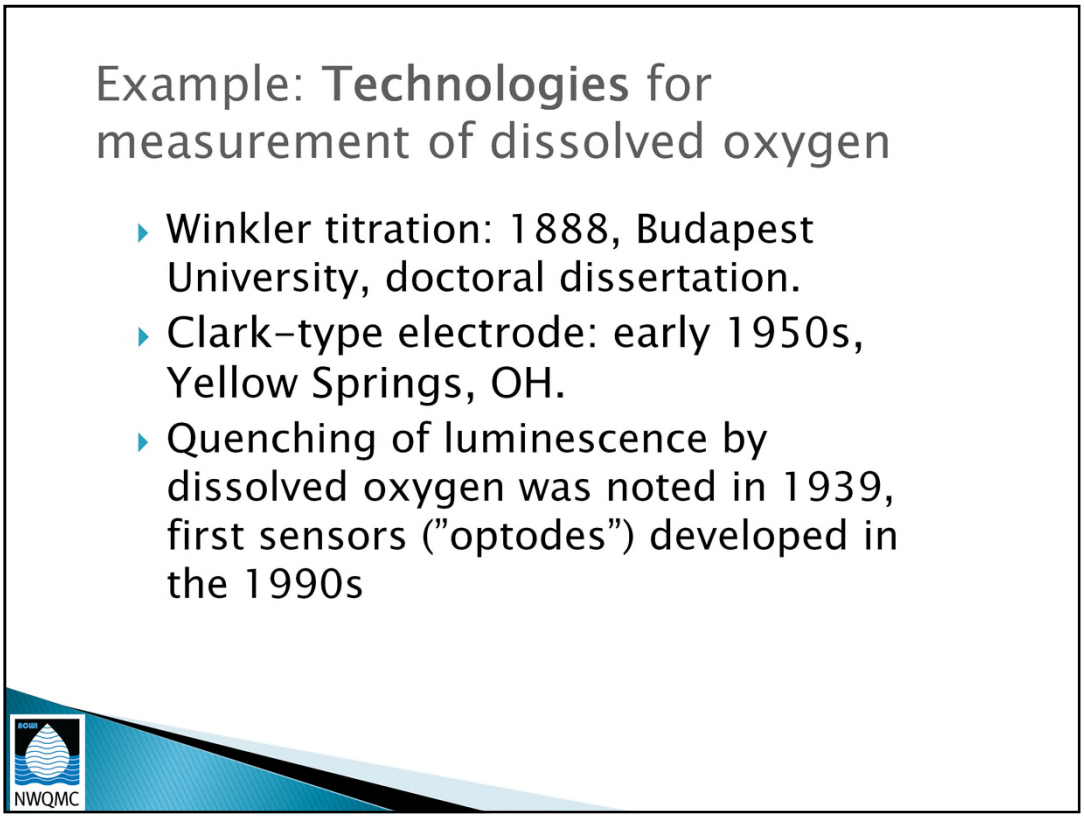
NWQMC 2014, Cincinnati, OH



Today's focus is on quality assurance actions that occur (i.e., need to be done) at four different levels by a variety of operators.



During the development of new measurement technologies, researchers run tests to prove that the measurement idea actually works and can produce a reliable signal that correlates well with the monitored characteristic. ACT – the Alliance for Coastal Technologies – works closely with developers to conduct demonstrations that focus on the capabilities and potential of emerging technologies.

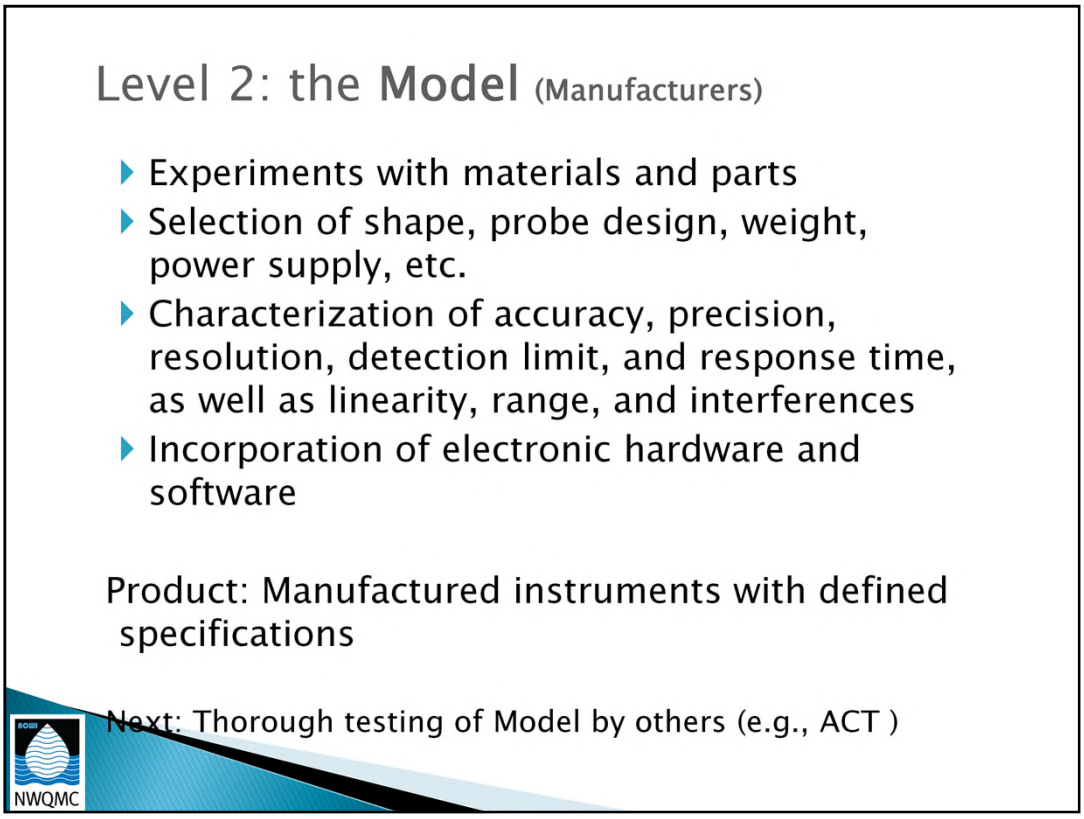


It is nice to see that we have moved a long way…

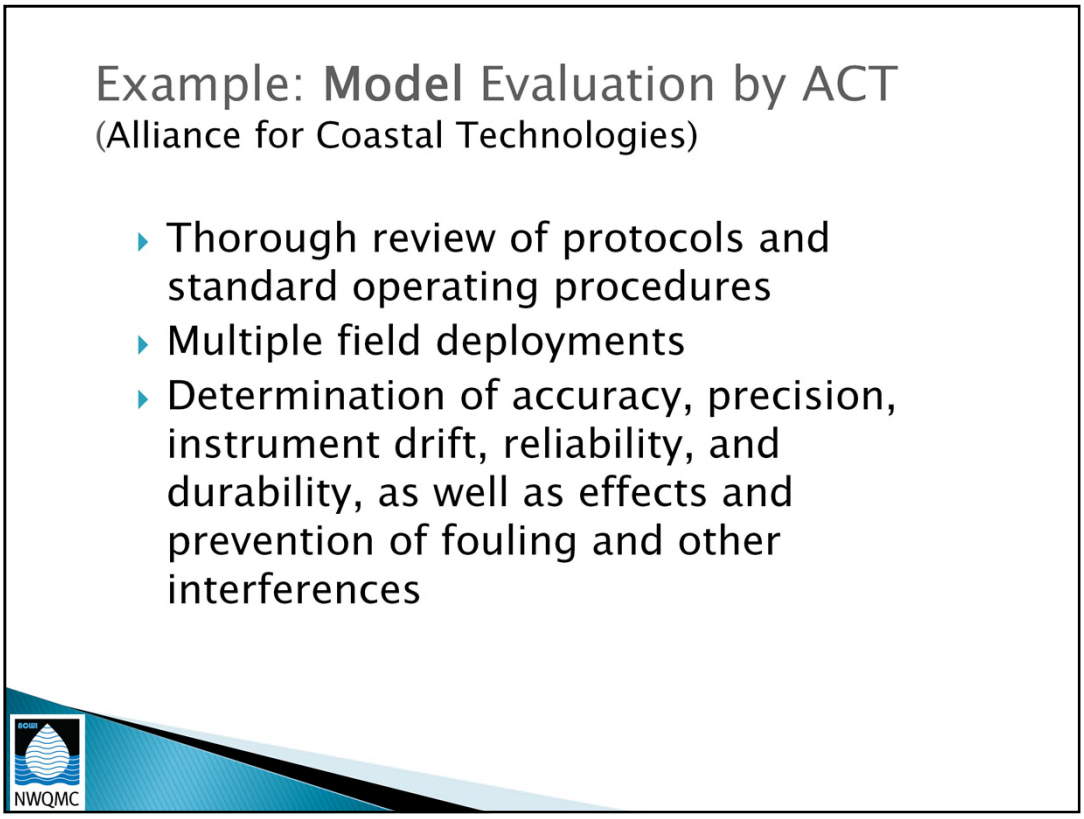
The **Winkler titration** is based on a chemical reaction between oxygen and another compound, which yields a product that can be quantified by titration with another chemical. This cannot be done in situ and involves an elaborate analytical process.

The **Clark-type electrode** (a.k.a. polarographic, or galvanic, electrode) utilizes the reduction-oxidation (redox) chemistry of oxygen in the presence of dissimilar metal electrodes. The sensor has an oxygen-permeable membrane that enables diffusion of the gas into an electrochemical cell; a low voltage is applied between the gold cathode and the silver anode and causes the oxygen to react electrochemically. Calibration of the sensor can be done is water-saturated air or oxygen-saturated water, but ground-truthing against the Winkler titration is often recommended as well. Polarographic electrodes revolutionized DO measurements in the field, but the probes (a) consumed oxygen, requiring constant mixing near the membrane's surface [this was somewhat alleviated in the 1980s by rapid-pulse voltage cycles], and (b) needed frequent calibration and maintenance (including assembling the membranes which calls for superior dexterity ☺)

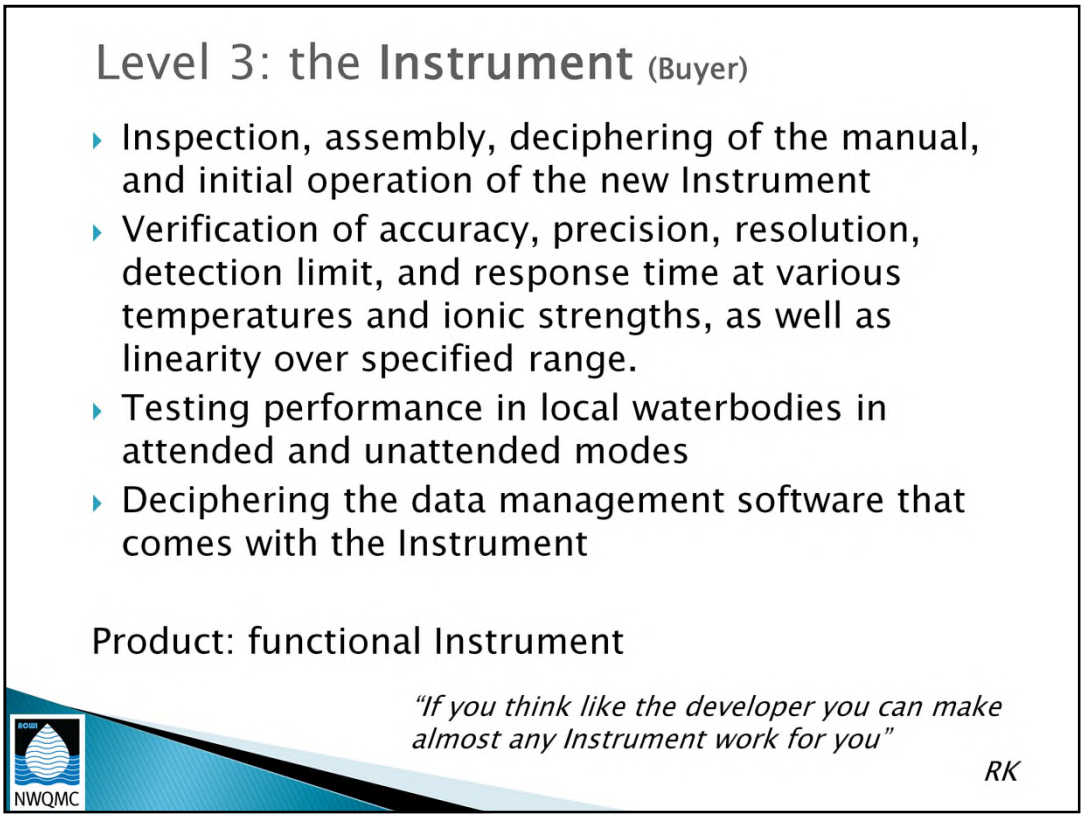
The **fluorescence-quenching** "optode" (a.k.a. Optical DO Sensor) has become available during the last two decades. The probe has a light-source which illuminates an oxygen-permeable membrane made with a fluorescent compound; the reduction in the fluorescence emission due to quenching by oxygen is measured by a light detector. Most optodes are low-maintenance probes that enable prolonged deployments and reliable signal even in harsh environments.



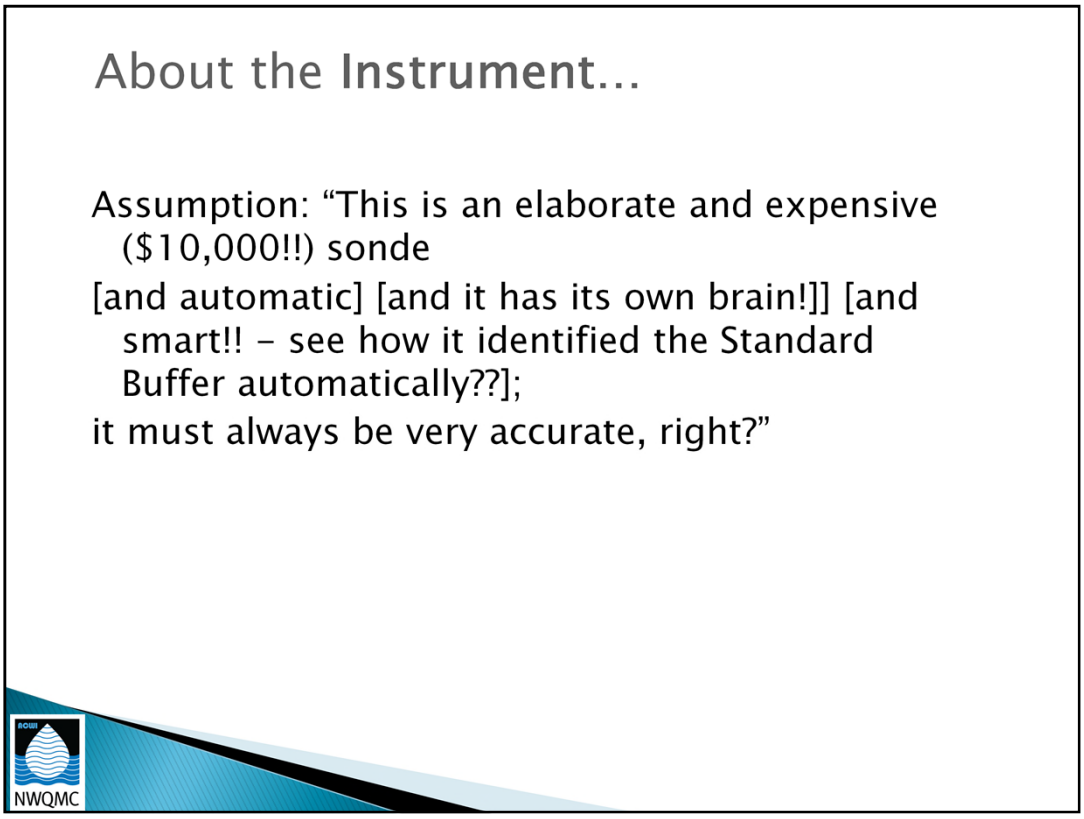
At the sensor Model level, manufacturers working on building a specific sensor model need to prove the functionality of that model as an established measurement system, and conduct comprehensive tests to derive the specifications for that model.



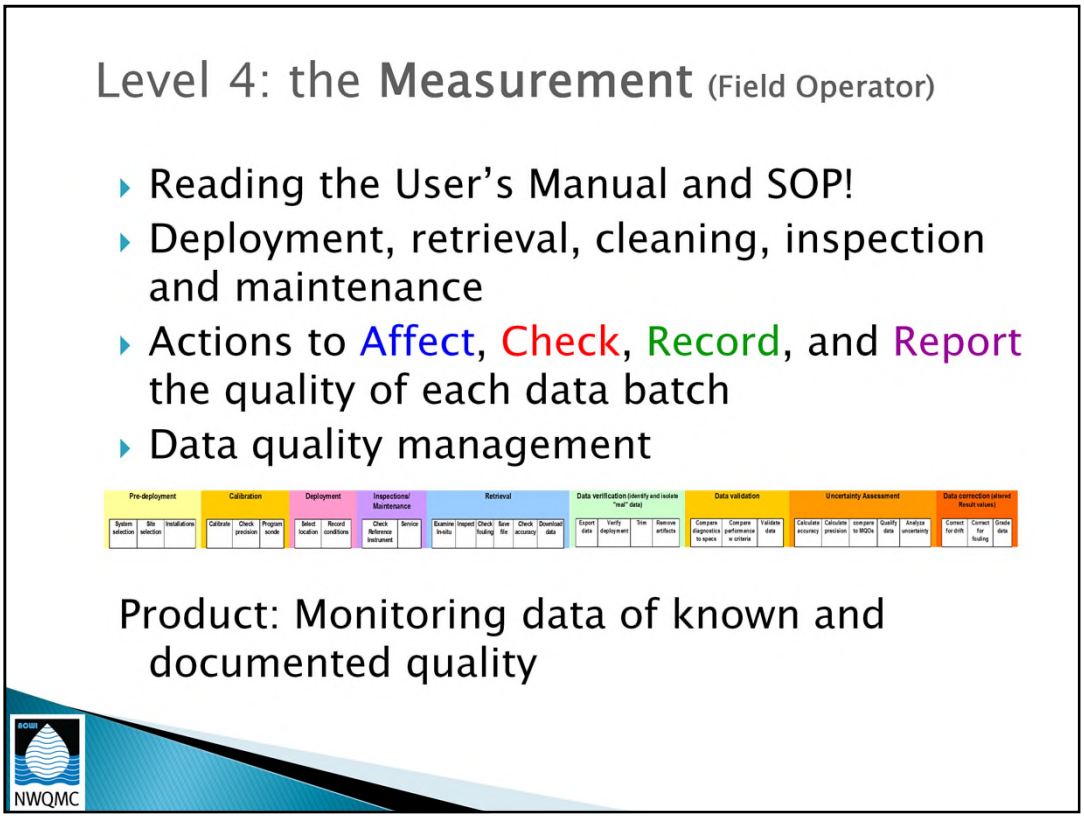
ACT serves as an unbiased, third party testing entity for evaluation of instrument performance and verification of model specifications. “Verifications are a 25-step process, which includes community consensus on test protocols, laboratory and field-testing, and QA/QC based on EPA and ISO guidelines. Field tests are carried out at no fewer than four but typically all six ACT partner sites.” Among many other things, they check accuracy, reproducibility, instrument drift, and reliability (defined as the ability to maintain integrity of the instrument and the data collections over time).



At the level of an individual Instrument, the Project person who opens the shipment box and prepares the instrument for use needs to go through a series of tests to assure that this instrument is functional and to establish its performance criteria as manifested in the environment relevant to his/her Project.



This assumption is very prevalent and very flawed. You may rely on all the good work that was done by the researchers, the developers, the manufacturers, and the reviewers, but there are so many things you need to check for yourself, and there are so many things your field operators must do when they use the instrument.



The fourth level is the Measurement (Activity in STORET language), e.g., a batch of data from one deployment episode. At this level, the field operator is implementing actions to Affect, Check, Record, and Report the quality of each data batch. This fourth level also involves a sequence of Data Quality Management functions, using sensor's diagnostic tests (i.e., physical and electronic operating conditions) to prove signal integrity, and using quality check outcomes to validate the data and to evaluate the extent of error and/or uncertainty.

Calibration: "Comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies and to report or eliminate those inaccuracies by adjustments" [USEPA].

May [should] be SEPARATED into…

Accuracy check: Comparison of the Instrument's reading with a value believed to be the "true" value, without adjustments of the reading. [report]

Calibration adjustment: The action of adjusting the reading of an instrument to have it match a "true" value. (Naturally, you do this after you run the accuracy check…). [eliminate]

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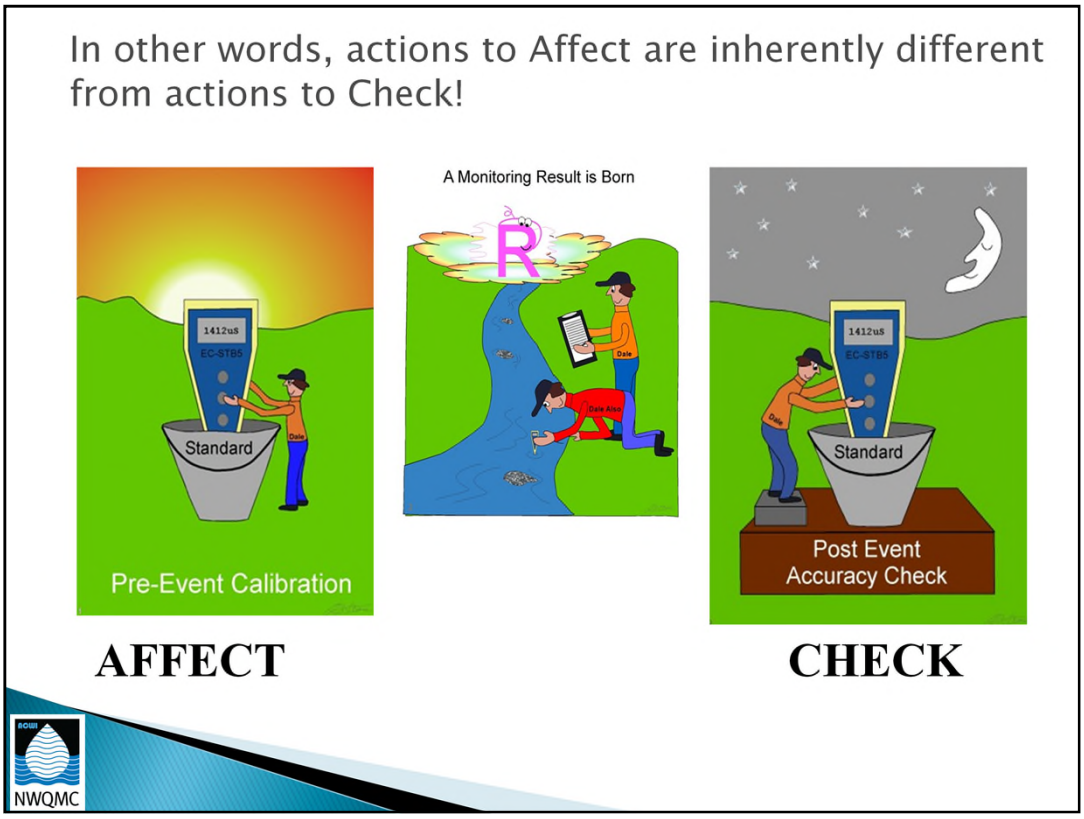
Language is important and it needs to be specific.



Quality Assurance Actions

Affect: Act to influence the outcome

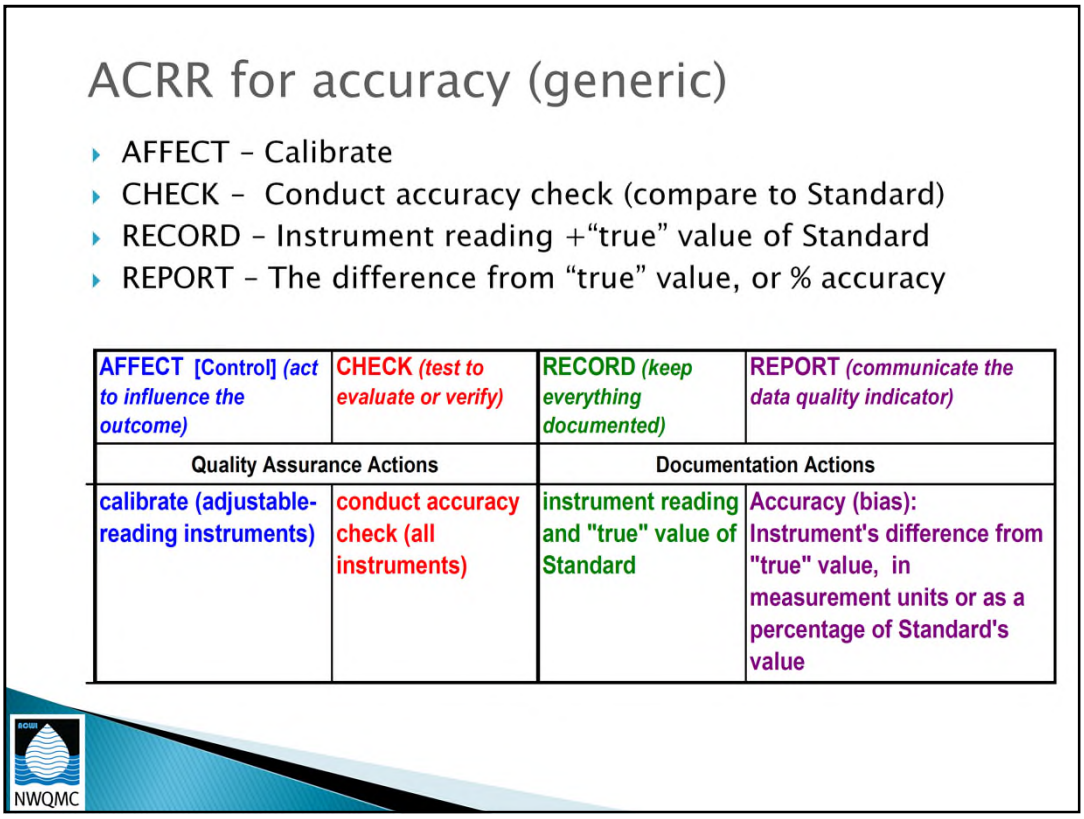
Check: Test to evaluate or verify

Documentation/Communication Actions

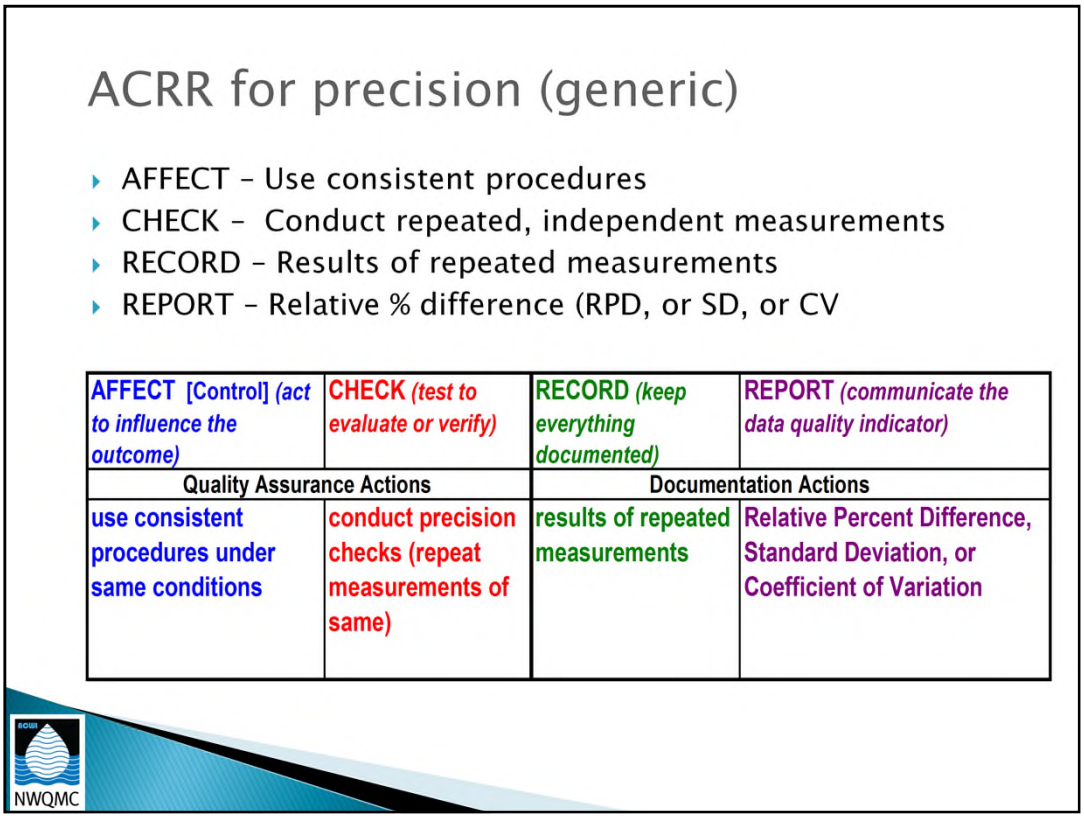
Record: Keep everything

documented

Report: Communicate the Quality Check outcome



The table shows a small selection of actions, all related to data accuracy.



Action to Affect, Check, Record, and Report measurement precision are very different from those conducted for accuracy. Both are needed.

(Matrix screenshot)

Technology	data quality aspect	Mode	AFFECT [Control] *(act to influence the outcome)*	Check *(test to evaluate or verify)*	Record *(keep everything documented)*	Report *(communicate the data quality indicator)*
			Quality Assurance Actions		Documentation Actions	
conductivity cell	**Accuracy /Bias**	Attended	Conduct one-point calibration in the lab, at a value in the middle of anticipated environmental range, at room temperature **[sp1-3]**, before each Trip. Conduct two point calibration in the field, at values that bracket expected range, at stream temperature, before first use of the day. Make sure the probe is properly hydrated before calibration and before each use; assure sufficient voltage	Conduct a one-point accuracy check in the lab, at a mid-range value, at room temperature **[sp2]**, within 24 hrs of Trip's end	Temperature of Standard, Instrument conductivity reading, temperature compensation factor (if needed), and "true" value of Standard	Report bias: Instrument drift, i.e., difference from known ("true") value of Standard, expressed either in measurement units or as percent of Standard's "true" value, whichever is higher.
	Accuracy/Bias	**Unattended**	Conduct two-point calibration in the lab, at zero and at value higher than expected range, at room temperature, before deployment and at every maintenance event (if needed)	Conduct three-point accuracy check, w Standards at min/mid/max values of expected range, plus a zero check in air, at room or field temperature, within 24 hrs of retrieval and at every maintenance event, before and after cleaning.	Temperature of Standard, Instrument conductivity reading, temperature compensation factor (if needed), and "true" value of Standard	Report bias: Instrument drift, i.e., difference from known ("true") value of Standard, expressed either in measurement units or as percent of Standard's "true" value, whichever is higher.
	Precision	Attended	use consistent procedures under same conditions	Repeat measurements 3-5 times after the reading has stabilized, under controlled (non-changing) environment in the lab, during every calibration or accuracy check event.	Results of the 3-5 measurements after stabilization;	Compute the Standard Deviation of the 3-5 values and report in measurement units **[a4]**
	Precision	**Unattended**	Use consistent procedures under same conditions	Repeat measurements 3-5 times after the reading has stabilized, under controlled (non-changing) environment in the lab, during every calibration or accuracy check event.	Results of the 3-5 measurements after stabilization;	Compute the Standard Deviation of the 3-5 values and report in measurement units **[a4]**
	Lack of interference or contamination	Attended	clean probes			
	Lack/Extent of interference or contamination	**Unattended**	clean probes, treat with anti-fouling agents, adjust deployment duration or maintenance intervals to local conditions	Run fouling comparison test: Measure stream water (in situ or in bucket) before and after cleaning the probe.	Pre-cleaning inspection and photographic records of fouling, Instrument readings before and after probe fouling removal	

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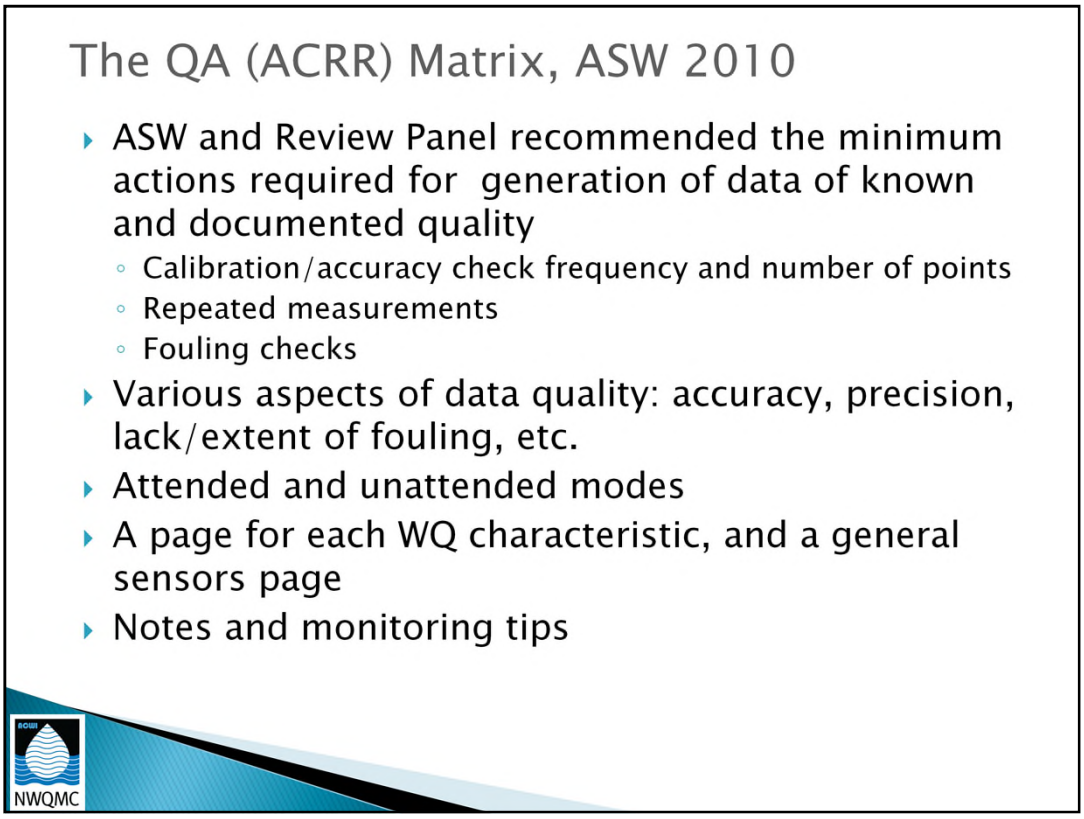
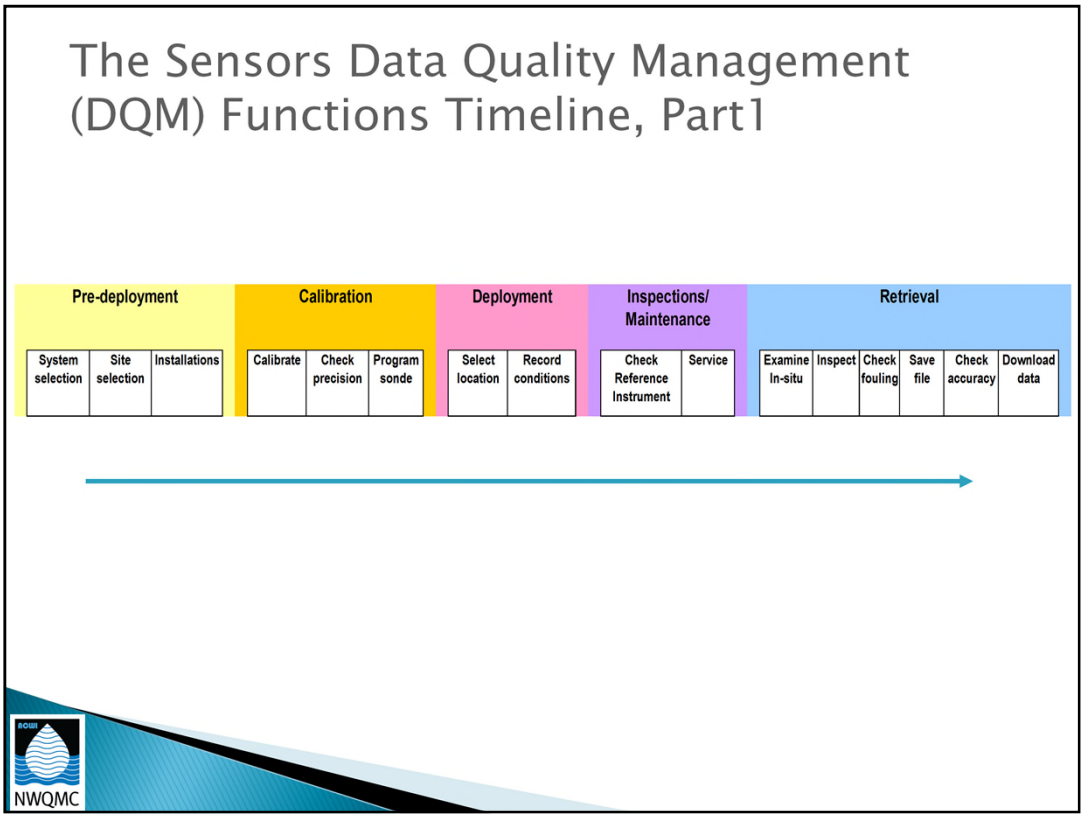
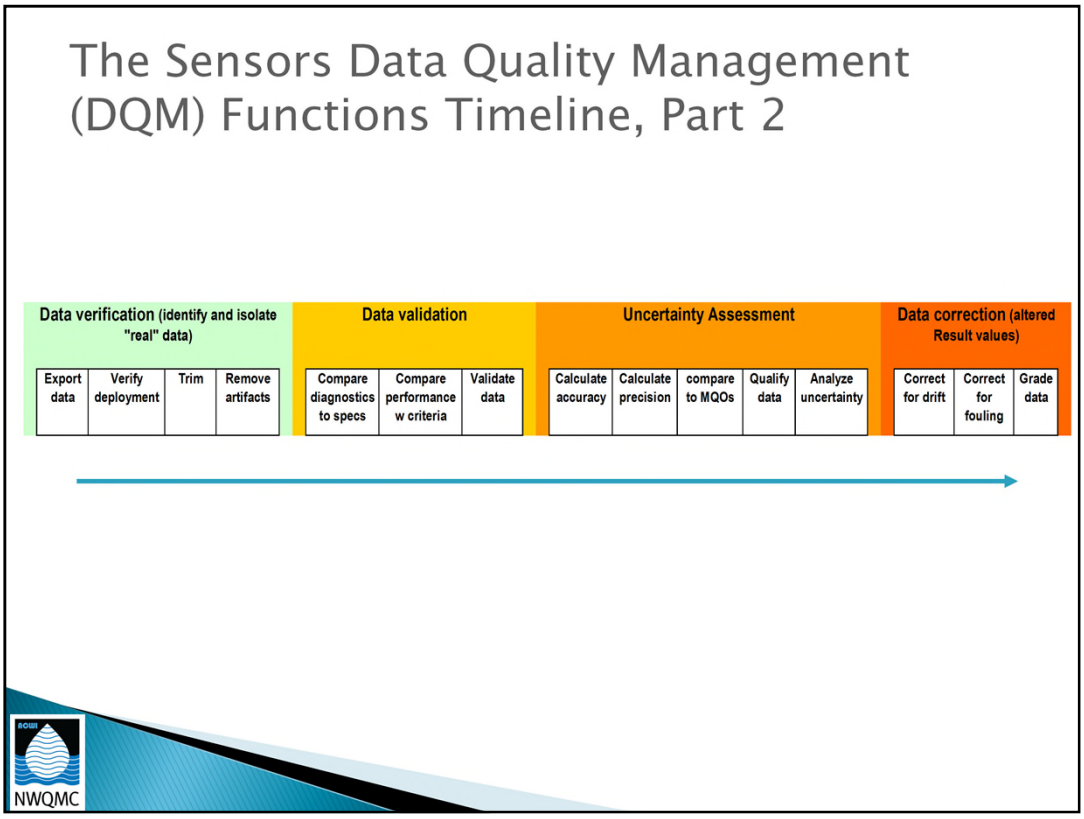
I worked with the aquatic sensors workgroup (ASW) to expand the ACRR matrix for all relevant aspects of data quality, and to create a separate matrix of actions for each characteristic and technology.



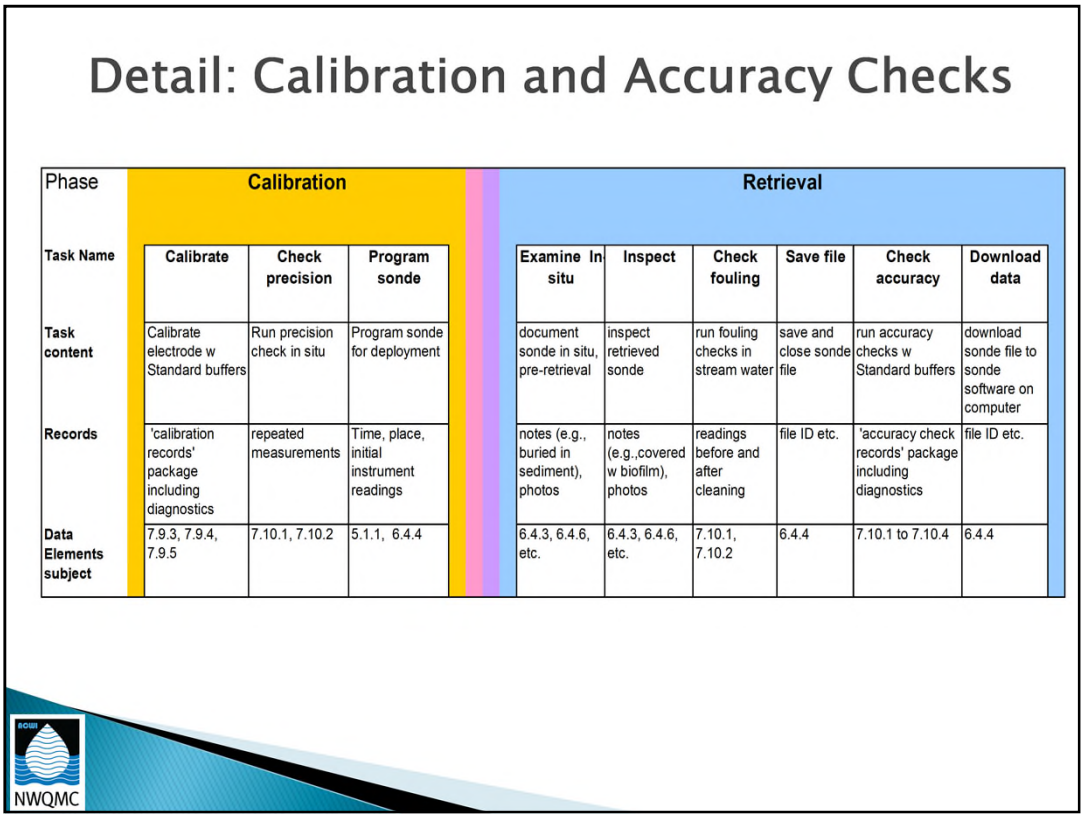
The ACRR matrix is a very useful checklist for field operators seeking concise guidance on how to assure and document the quality of data they are gathering..



Beyond all the ACRR actions, there are a number of other things operators need to do in order to deliver data of known and documented quality. The sequence of Data Quality Management (DQM) functions, shown here as a timeline, includes some ACRR actions embedded in many other functions such as data validation and verification – as also seen in the next slide.



Verification is about making sure that what you deliver as data was indeed a property of the monitored environment (not an artifact). Validation confirms that the measurement system worked properly and according to specifications. Error calculation is part of the validation in that it confirms that the measurement system worked within its performance criteria (i.e., was not broken). Correction of sensor data due to drift or fouling is sometimes called for, and it is important to do the corrections in the same way that other data gatherers do so the data is comparable.



This is a zoom-in on two phases of the Data Quality Management Timeline. The functions timeline specifies what needs to be recorded with each task, i.e., which “bits of information”, or data elements, need to be captured. The ASW provides a list of Sensors data elements organized by subject matter in seven categories: The Project (who), the Result (what), the reason (why), the time (when), the location (where), the field activity (sample, observation, etc.), and the measurement system (how, and how good).

Sensors data processing, from A to Z

U.S. Geological Survey (USGS) conducted the **Value Engineering Study – Water Quality (2009),** working with the Interstate Council on Water policy (ICWP); study recommendations included (among others):

- Automate/streamline data entry and processing
- Consolidate functionalities of multiple software programs into one solution (identified nine different software programs in use)

More from the Real World: many people are calling for streamlining and consolidation.

Error and Correction

Phase	Uncertainty Assessment					Data correction (altered Result values)		
Task Name	**Calculate accuracy**	**Calculate precision**	**compare to MQOs**	**Qualify data**	**Analyze uncertainty**	**Correct for drift**	**Correct for fouling**	**Grade data**
Task content	calculate measurement accuracy for this episode	calculate measurement precision (for this episode?)	compare quality check outcomes to MQOs	select qualifier for 'met MQOs' (or not) or for error range	run an uncertainty analysis	correct data for instrument drfit	correct data for sensor fouling	assign a quality-grade to the data based on the extent of correction
Records	Quality check outcome: diffrential, percent of Standard	Quality check outcome: Relative Percent Difference	values of MQOs	met/did not meet MQOs	confidence intervals or level	algorithm used, date/time corrected		quality grade
Data Elements subject	7.10.2, 2.3.5	7.10.2, 2.3.5	2.3.6	2.3.6	2.3.5	2.3.3, 8.3.1	2.3.3, 8.3.1	2.3.3

Do we have common rules and criteria for data correction? Do we (should we) use the same correction algorithms and the same grading system?

This is a zoom-in on two other phases of the Data Quality Management Timeline: assessment of uncertainty and data correction. Rules and criteria for data correction, as well as the correction algorithms, need to be the same across the board for data sharing to work.

Correction of Sensors' Data

Looked for guidance, tried a number of keyword combinations… Found an internal USGS memo,

"Office of Water Quality Technical Memorandum 2012.04" which talks about "Auto-correction loader (ACL) Program automates the computation and loading of data corrections directly from SiteVisit into ADAPS"

- Problem: these evolving tools are moving targets; rules and criteria for data correction are not permanently established (?)
- Need to improve public accessibility/ease of finding (i.e., relevant information should not be hidden)
- Not all agencies are looking for common tools; some create their own (incompatible?) systems

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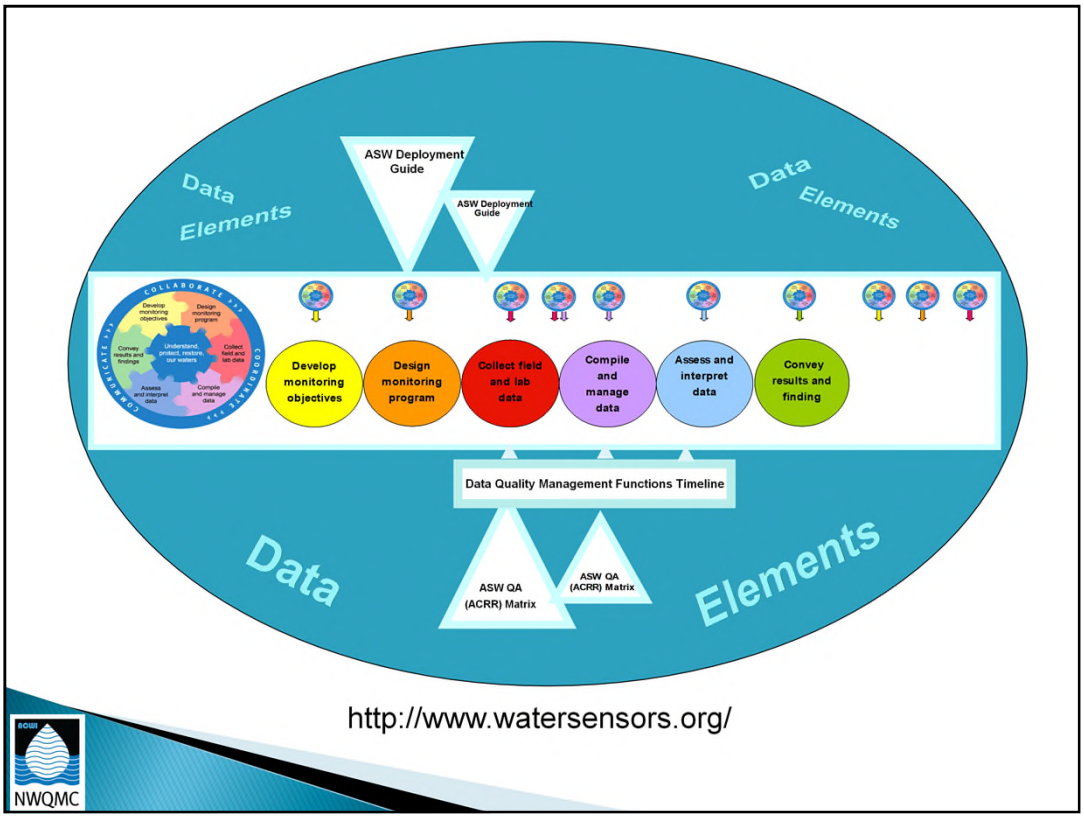
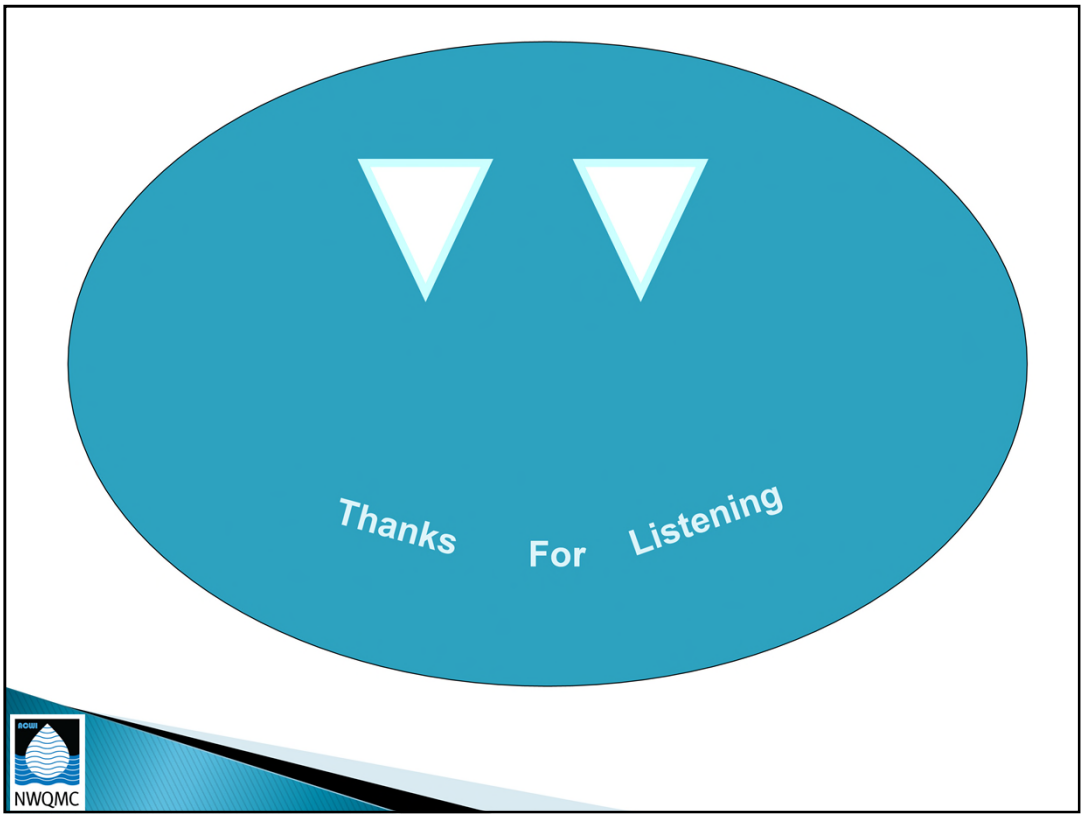
How many of you tried to find guidance for data correction?



However, the tools that have been introduced by the Aquatic Sensors Workgroup (ASW) are very accessible! The ASW is a workgroup of the Methods and Data Comparability Board affiliated with the National Water Quality Monitoring Council.



Thanks